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(71) Applicant
United Kingdom Atomic Energy Authority

(Incorporated in the United Kingdom)

11 Charles II Street, London, SW1Y 4QP,
United Kingdom

(72) Inventor
Stefan Richard Martin

(74) Agent and/or Address for Service
Peter Turquand Mansfield
Patents Branch, Building 329, Harwell Laboratory,
Oxfordshire, OX11 0RA, United Kingdom

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(54) Optical scanner

(57) An optical scanning apparatus scans a light beam in a circular path to detect defects in a circular object. The apparatus includes an optical assembly (28) to deviate and focus a light beam into an elliptical focal spot, the assembly being rotated so the beam envelopes a cone. The assembly comprises at least one cylindrical lens (50, 52), two small-angle wedge prisms (54), and annular wedge-shaped balance pieces (55) to provide dynamic balancing of the assembly. This minimizes vibration during rotation. Light reflected by an object is then sensed by a photodetector.

Fig. 2.

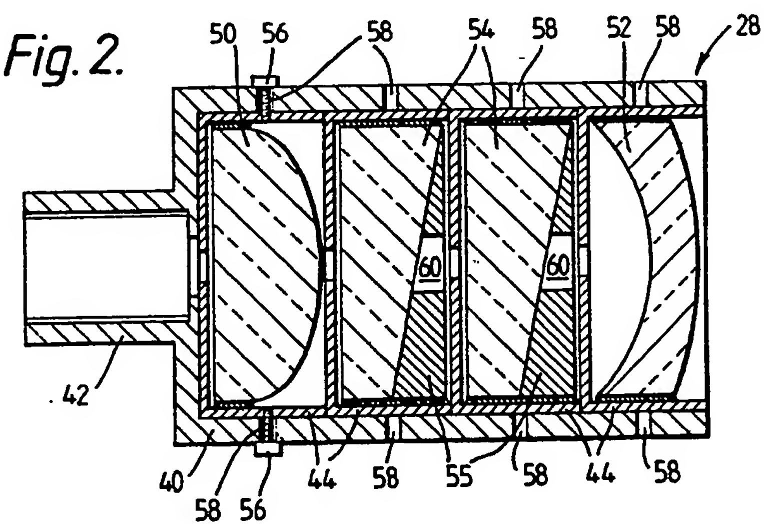

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Fig. 1.

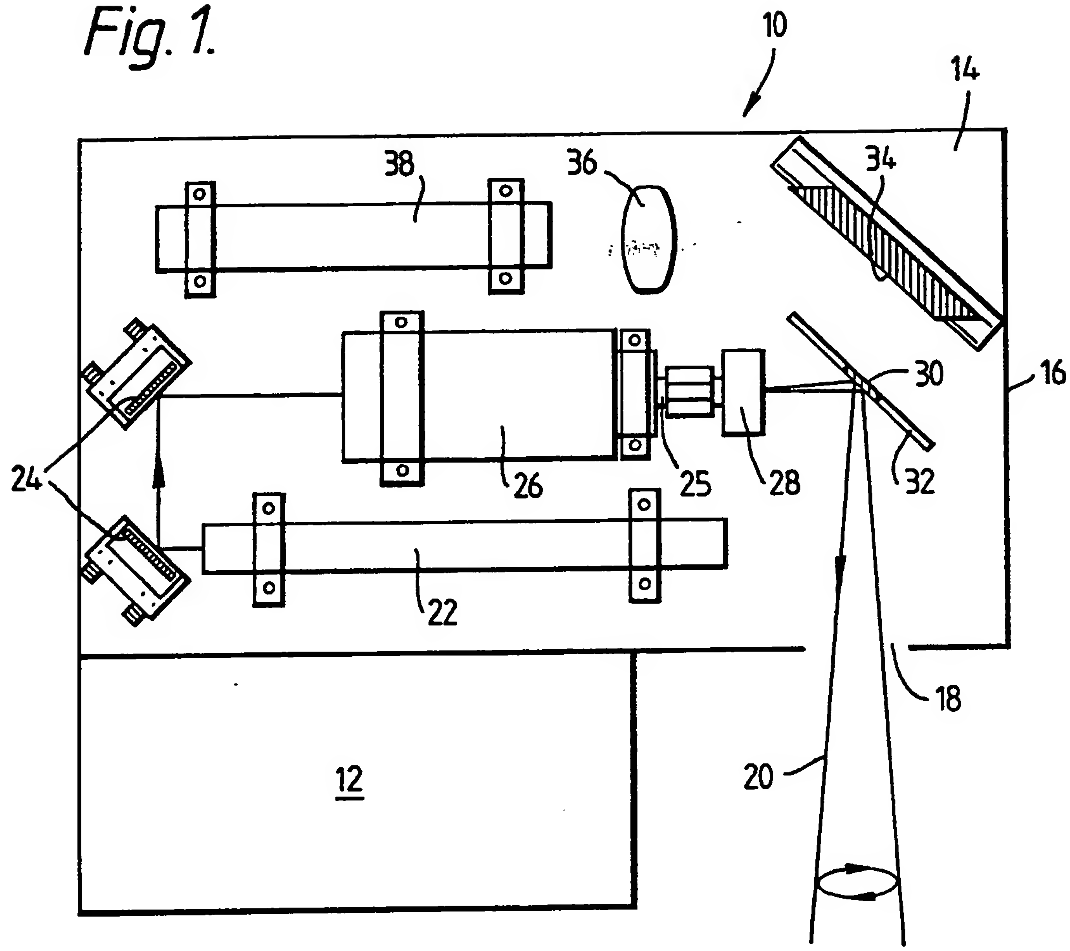
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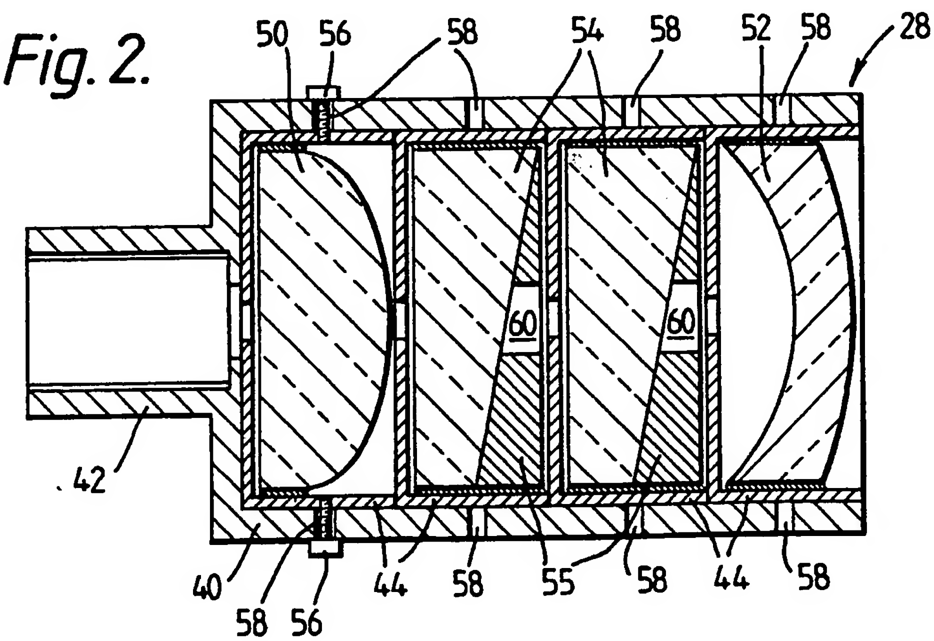
Fig. 2.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Optical Scanner

This invention relates to an optical scanner suitable for inspecting circular or cylindrical objects for cracks, notches, or non-circularity.

For inspecting the inner surfaces of glass bottles for dirt it is known from GB 1 182 413 to use a beam of ultraviolet light scanned helically over the inner surface, light generated in the glass by fluorescence returning along the optical path followed by the incident radiation to be reflected by a dichroic mirror to a sensor. The scanning mechanism includes a hollow tube along which the radiation passes, with at one end a mirror assembly. The difference in frequency between the incident radiation and the fluorescence is an essential feature of the technique, so that the technique is applicable only if either the glass or the dirt fluoresces.

According to the present invention there is provided an optical scanning apparatus for inspecting an object to detect any surface defects or deviations from circularity, the apparatus comprising an optical assembly, means to rotate the optical assembly, means to provide a light beam arranged such that in operation the light beam propagates through the optical assembly to be incident on the object, and means to sense light reflected from the object, the optical assembly comprising at least one cylindrical lens, two small angle wedge prisms arranged to deviate the light beam by refraction, one of the prisms being turnable relative to the other prism to adjust the angle of deviation, and two wedge shaped balance pieces to counterbalance the asymmetry in the distribution of mass of the wedge prisms, each balance piece defining an aperture for the light beam.

The light sensor is generally arranged to sense light which has been diffusely reflected by the object, rather than specularly reflected light.

The combination of lenses, wedges and balance pieces forming the optical assembly enables the shape of the scanning spot to be adjusted and enables the angle through which the light beam is deviated to be adjusted, while ensuring that rotation of the assembly does not generate any vibrations or oscillatory forces on the rotation means. This is an important consideration where the rate of rotation is high, for example 60 Hz or 70 Hz.

The invention will now be further described by way of example only, and with reference to the accompanying drawings in which:

Figure 1 shows a diagrammatic side view of an optical scanning apparatus;

Figure 2 shows a longitudinal sectional view of the optical assembly of the apparatus of Figure 1.

Referring to Figure 1, an optical scanning apparatus 10 comprises a rectangular base section 12 containing electrical and electronic components (not shown), and an upper rectangular section 14 in a metal housing 16 containing the optical components. The upper section 14 projects beyond the base section 12 at one end and a circular aperture 18 is defined in the housing 16 of that part, through which a scanning light beam 20 emerges.

The light beam 20 is generated by 5 mW helium/neon laser 22 and is reflected by two adjustable plane mirrors 24 so as to pass axially along the hollow shaft 25 of a

printed armature dc servo motor 26. Attached to the other end of the shaft 25 is an optical assembly 28 (described in more detail below) which deviates the light beam 20, so that as the shaft 25 rotates the emerging beam 20 scans conically. A small elliptical mirror 30 reflects the beam 20 out through the aperture 18; the mirror 30 is an aluminised and hard coated area on a plane glass sheet 32.

Light from the beam 20 scattered back after reflection from an object being scanned may pass through the aperture 18 and the non-reflecting parts of the glass sheet 32, to be incident on a plane elliptical mirror 34. This reflects the light through a converging lens 36 onto a photomultiplier 38. As the light beam 20 scans around an object the variations in the electrical signals generated by the photomultiplier 38 represent the variations in reflectivity or surface texture of the object. The light beam 20 traces out a circular path on any flat object arranged perpendicular to the axis of the cone, and so is particularly suitable for detecting surface defects in circular objects such as electric cells, O-rings, or tins.

Referring now to Figure 2, the optical assembly 28 is enclosed in a cylindrical tubular housing 40, open at one end and communicating with an open-ended tubular internally-threaded socket 42 at the other end whereby the assembly 28 is attached to the hollow shaft 25. Within the housing 40 are four short cylindrical optical mounts 44 each with a cylindrical wall and one end wall defining an axial aperture for the light beam 20; the mounts 44 butt up against each other. Cemented into two of the mounts 44 are lenses 50, 52, with cylindrically curved optical surfaces; one lens 50 is a low power converging lens (focal length about + 300 mm) and the other lens 52 is a higher power diverging lens (focal length about - 90 mm), and the lenses 50 and 52 are arranged so that the axes of the cylindrically curved optical surfaces are at right

angles to each other. In the other two mounts 44 are glass wedge prisms 54 and aluminium balance pieces 55 (the shape of the prisms 54 is shown diagrammatically, the angle of the wedge being exaggerated for clarity). Each mount 44 is held in a particular orientation by a pair of screws 56 engaging in diametrically opposed, correspondingly threaded holes in the mount 44, the screws 56 extending through slots 58 in the housing 40 (only one pair of screws 56 is shown); each slot 58 extends around a quarter of the periphery of the housing, so that the orientation of each mount 44 can be adjusted over a range of 90 degrees.

Each balance piece 55, and indeed each prism 54, is of circular shape if viewed along the axis of rotation of the mount 44, and of the same external diameter as the prism 54. The adjacent faces of the prism 54 and of the balance piece 55 are inclined at the same wedge angle, so when assembled together they form a right cylindrical object. A circular hole 60 is defined through the centre of each balance piece 55 both for passage of the light beam 20 and also to ensure the assembly is dynamically balanced; this is achieved by having the diameter of the hole 60 equal to the external diameter of the balance piece 55 multiplied by the fourth root of the fraction: difference between the densities of glass and of aluminium divided by the density of aluminium. The resulting optical assembly 28 has been found to be sufficiently well balanced to create negligible vibration even when rotating at 70 Hz.

It will be understood that the angle through which the light beam 20 is deviated by the optical assembly 28, and so the radius of the circular scan, can readily be adjusted by turning the mount 44 containing one prism 54 relative to that containing the other. In this embodiment the angle of deviation can be adjusted between zero and ten degrees. The mounts 44 containing the lenses 50 and 52 are

preferably adjusted so the beam 20 is diverged in the plane of the incoming and the deviated light beams 20, while being converged in the plane at right angles. This ensures that the scanning spot is elliptical in shape with its long axis at all times directed towards the centre of the scan.

The scanning apparatus 10 may be used on a production line to detect defective objects. The objects would be aligned and presented to the apparatus 10 sequentially, scanned for at least one revolution of the beam 20, and then moved on. Defects may be detected by monitoring the variations in the signal produced by the photomultiplier 38 and noting any signal variations exceeding a threshold value. If the objects are moving, an additional circuit may be used to detect when the object is centred on the scan, this being done by integrating the signal intensity during a complete revolution. If light coloured objects are viewed against a dark background then the integrated signal increases to a maximum when the object is centred. This can for example be detected by a threshold circuit, and used to trigger a transient recorder to record the signals during the next revolution, for analysis.

Claims

1. An optical scanning apparatus for inspecting an object to detect any surface defects or deviations from circularity, the apparatus comprising an optical assembly, means to rotate the optical assembly, means to provide a light beam arranged such that in operation the light beam propagates through the optical assembly to be incident on the object, and means to sense light reflected from the object, the optical assembly comprising at least one cylindrical lens, two small angle wedge prisms arranged to deviate the light beam by refraction, one of the prisms being turnable relative to the other prism to adjust the angle of deviation, and two wedge shaped balance pieces to counterbalance the asymmetry in the distribution of mass of the wedge prisms, each balance piece defining an aperture for the light beam.

2. An apparatus as claimed in Claim 1 wherein both the prisms are of the same angle and are such that the angle of deviation can be adjusted between zero and about ten degrees.

3. An apparatus as claimed in Claim 1 or Claim 2 wherein the angle of each wedge shaped balance piece is equal to the angle of the corresponding wedge prism.

4. An apparatus as claimed in Claim 3 wherein each balance piece is of the same external diameter as the corresponding prism, and the aperture is circular, coaxial with the axis of rotation of the assembly, and of diameter equal to the external diameter of the balance piece multiplied by the fourth root of the fraction:

$$\frac{D - d}{d}$$

where D is the density of the material of the prism and d is the density of the material of the balance piece.

5. An apparatus as claimed in Claim 3 or Claim 4 wherein each wedge prism is immediately adjacent to the corresponding balance piece, the adjacent faces of the prism and of the balance piece being inclined at the same wedge angles to the axis of rotation of the assembly, and the external faces of the prism and of the balance piece being perpendicular to the axis of rotation.

6. An optical scanning apparatus for inspecting an object to detect any surface defects or deviations from circularity, substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

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